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7864

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 :
H01L 21/00, B08B 3/12

A1

(11) International Publication Number: WO 98/14985

(43) International Publication Date: 9 April 1998 (09.04.98)

(21) International Application Number: PCT/US97/11812

(22) International Filing Date: 8 July 1997 (08.07.97)

(30) Priority Data:
08/724,518 30 September 1996 (30.09.96) US

(81) Designated States: CN, JP, KR, SG, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

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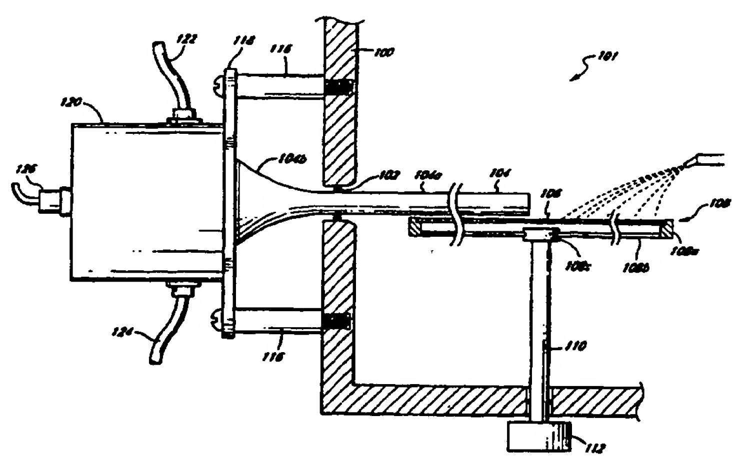
(54) Title: WAFER CLEANING SYSTEM



(57) Abstract

A wafer cleaning system cleans semiconductor wafers using megasonic energy to agitate cleaning fluid applied to the wafer. A source of acoustic energy vibrates an elongated quartz probe which transmits the acoustic energy into the fluid. One form of the probe has a solid cylindrical–shaped cleaning portion within the tank and a flared rear portion with an increasing diameter outside the tank. A heat transfer member acoustically coupled to the larger rear portion of the probe and to a transducer conducts heat away from the transducer. A housing for the heat transfer member and transducer supports those components and provides means for conducting coolant through the housing to control the temperature of the transducer. In one arrangement, fluid is sprayed onto both sides of a wafer while a probe is positioned close to an upper side. In another arrangement, a short probe is positioned with its end face close to the surface of a wafer, and the probe is moved over the wafer as it rotates. The probe may also be positioned through a central hole in a plurality of discs to clean a group of such elements at one time.

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WAFER CLEANING SYSTEM

Field of the Invention

This invention relates to an apparatus and method for cleaning semiconductor wafers or other such items requiring extremely high levels of cleanliness.

Background of the Invention

Semiconductor wafers are frequently cleaned in cleaning solution into which megasonic energy is propagated. Megasonic cleaning systems, which operate at a frequency over twenty times higher than ultrasonic, safely and effectively remove particles from materials without the negative side effects associated with ultrasonic cleaning.

Megasonic energy cleaning apparatuses typically comprise a piezoelectric transducer coupled to a transmitter. The transducer is electrically excited such that it vibrates, and the transmitter transmits high frequency energy into liquid in a processing tank. The agitation of the cleaning fluid produced by the megasonic energy loosens particles on the semiconductor wafers. Contaminants are thus vibrated away from the surfaces of the wafer. In one arrangement, fluid enters the wet processing container from the bottom of the tank and overflows the container at the top. Contaminants may thus be removed from the tank through the overflow of the fluid.

A gas impingement and suction cleaning process for electrostatographic reproducing apparatuses which utilizes ultrasonic energy and air under pressure is disclosed in U.S. Patent No. 4,111,546, issued to Maret.

A process for cleaning by cavitation in liquefied gas is disclosed in U.S. Patent No. 5,316,591, issued to Chao et al. Undesired material is removed from a substrate by introducing a liquefied gas into a cleaning chamber and exposing the liquefied gas to cavitation-producing means. The shape of the horn to provide the cavitation is not disclosed in detail and does not concentrate the sonic agitation to a particular location within the cleaning vessel.

In U.S. Patent No. 4,537,511, issued to Frei, an elongated metal tube in a tank of cleaning fluid is energized in the longitudinal wave mode by a transducer that extends through a wall of the tank and is attached to the end of the tube. In order to compensate for relatively high internal losses, the radiating arrangement uses a relatively thin-walled tubular member.

A need exists for an improved apparatus and method which can be used to clean semiconductor wafers.

Summary of the Invention

In one embodiment of the present invention, a vibrator, such as a source of acoustic energy, vibrates an elongated probe which extends into a cleaning tank to clean the surface of articles in close proximity with the probe. A heat transfer member is attached to the rear of the probe to control the temperature of the apparatus. A piezoelectric transducer acoustically coupled to the heat transfer member and connected to a source of megasonic energy provides a means for vibrating the probe.

The elongated probe is made of quartz or some other relatively inert, non-contaminating material which efficiently transmits acoustic energy. The probe comprises a tip portion, a cleaning portion, and a rear portion. The cross-section of the probe is preferably round, and the diameter of the cross-section of the cleaning portion of the probe is smaller in diameter than the cross-section of the rear portion of the probe so as to concentrate the energy. The cleaning portion of the probe preferably has a constant diameter to form a solid cylindrical-shaped section.

From the constant diameter of the cylindrical-shaped section, the cross-section of the rear portion of the probe flares or increases. In a first embodiment, the diameter of the cross-section of the rear portion of the probe gradually increases. In an alternative embodiment of the present invention, the diameter of the cross-section of the rear portion of the probe increases in stepped increments.

In one embodiment, the probe is acoustically coupled to a spool-shaped, gold-plated, aluminum heat transfer member. In one arrangement the probe is bonded to the heat transfer member, and in another, the probe is coupled to the heat transfer member under spring pressure.A transducer is acoustically coupled to the other side of the heat transfer member, and both the heat transfer member and the transducer are contained within a housing. The housing has an inlet and an outlet for coolant which controls the temperature of the probe and the transducer and an electrical convertor for RF energy.

The housing is mounted to the exterior of the processing tank and provides support for the probe which is positioned through an opening of the processing tank wall. The probe is positioned parallel to and in close proximity to a semiconductor wafer. Spacers or stand-offs advantageously position the transducer and larger rear portion of the probe outside the tank so that only the smaller diameter cleaning portion of the probe and the probe tip extend into the tank.

In use, the processing tank may be filled with fluid, a wafer positioned on a support within the processing tank, close to the probe, on the inner surface and the probe is vibrated megasonically causing fluid in the tank to be agitated. The wafer is rotated or otherwise moved in relation to the probe so that the entire surface of the wafer to be cleaned comes within close proximity to the probe. With a different probe mounting arrangement, the probe can be moved relative to the wafer.

Instead of being immersed in fluid, the probe may be positioned adjacent a wafer surface onto which fluid is sprayed. Megasonic energy is conducted through the fluid layer, and loosened particles are carried away by the liquid.

In another arrangement, discs having a central hole may be cleaned by having the probe extend through one or more discs positioned in a tank.

Brief Description of the Drawings

Figure 1 is a side elevational view of one embodiment of the megasonic energy cleaning system of the present invention.

Figure 2 is a side cross-sectional view of the system shown in Figure 1.

Figure 3 is an exploded perspective view of the probe assembly shown in Figure 1.

Figure 4 is a side view of an alternative probe in accordance with the present invention.

Figures 5a-5c are alternative probe tips which may be used in connection with the present invention.

Figure 6 is a schematic view of the probe of the present invention used with cleaning fluid being sprayed onto the upper surface of a wafer.

Figure 7 is a cross-sectional view on line 7-7 of Figure 6.

Figure 8 is a schematic view of the probe cleaning both surfaces of a wafer.

Figure 9 is a schematic view of the probe of Figure 1 extending through discs to be cleaned.

Figure 9a is a fragmentary, cross sectional view of a cap for a probe tip.

Figure 9b is a fragmentary, cross sectional view of another probe tip cap.

Figure 10 is a schematic view of a probe vertically oriented with respect to a wafer.

Figure 11 a side elevational partially sectionalized view of another embodiment of the invention having an alternative means of coupling the probe to a support.

Detailed Description of the Preferred Embodiment

Figures 1-3 illustrate a megasonic energy cleaning apparatus made in accordance with the present invention with an elongated probe 104 inserted through the wall 100 of a processing tank 101. As seen, the probe is supported in cantilever fashion on one end exterior of the container. A suitable O-ring 102, sandwiched between the probe 104 and the tank wall, provides a proper seal for the processing tank 101. A heat transfer member 134, contained within a housing 120, is acoustically and mechanically coupled to the probe 104. Also contained within the housing 120 is a piezoelectric transducer 140 acoustically coupled to the heat transfer member 134. Electrical connectors 142, 154, and 126 are connected between the transducer 140 and a source of acoustic energy (not shown).

The housing supports an inlet conduit 124 and an outlet conduit 122 for coolant and has an opening 152 for electrical connectors. The housing is closed by an annular plate 118 with an opening 132 for the probe. The plate in turn is attached to the tank.

Within the processing tank 101, a support or susceptor 108 is positioned parallel to and in close proximity to the probe 104. The susceptor 108 may take various forms, the arrangement illustrated including an outer rim 108a supported by a plurality of spokes 108b connected to a hub 108c supported on a shaft 110, which extends through a bottom wall of the processing tank 101. Outside the tank 101, the shaft 110 is connected to a motor 112.

The elongated probe 104 is preferably made of a relatively inert, non-contaminating material, such as quartz, which efficiently transmits acoustic energy. While utilizing a quartz probe is satisfactory for most cleaning solutions, solutions containing hydrofluoric acid can etch quartz. Thus, a probe made of sapphire or silicon carbide or boron nitride may be employed instead of quartz. Also, quartz may be coated by a material that can withstand HF such as silicon carbide or vitreous carbon.

The probe 104 comprises a solid, elongated, constant cross-section cleaning portion 104a, and a rear portion 104b. The cross-section of the probe is preferably round and advantageously, the diameter of the cleaning portion of the probe is smaller in diameter than the rear portion of the probe. In a prototype arrangement the area of the rear face of the rear portion 104b is 25 times that of the tip face of portion 104a. Of course, cross-sectional shapes other than circular may be employed.

A cylindrically-shaped cleaning section 104a having a small diameter is desirable to concentrate the megasonic energy along the length of the section 104a. The diameter of the probe, however, should be sufficient to withstand mechanical vibration produced by the megasonic energy transmitted by the probe. In a

prototype, the cross-section diameter of the cylindrical portion of the probe contained within the tank was approximately .4 of an inch.

The probe cleaning portion 104a should be long enough so that the entire surface area of the wafer is exposed to the probe during wafer cleaning. In a preferred embodiment, because the wafer is rotated beneath the probe, the length of the cleaning portion 104b should be long enough to reach at least the center of the wafer. Therefore, as the wafer is rotated beneath the probe, the entire surface area of the wafer is close to the probe. Actually, the probe could probably function satisfactorily even if it does not reach the center of the wafer since megasonic vibration from the probe tip would provide some agitation towards the wafer center.

The length of the probe is also determined by a predetermined number of wavelengths. In one embodiment, the length of the probe cleaning portion 104a equals nineteen wavelengths of the applied energy.

The rear probe portion 104b, which is positioned exterior the tank, flares to a diameter larger than the diameter of the cleaning portion 104a. In a first embodiment of the present invention, shown in Figures 1-3, the diameter of the cross-section of the rear portion of the probe gradually increases to a cylindrical section 104d. The large surface area at the end of the rear portion 104d is advantageous for transmitting a large amount of megasonic energy which is then concentrated in the smaller diameter section 104a.

As illustrated in Figure 4, in an alternative embodiment of the present invention, the diameter of the cross-section of the rear portion of the probe increases in stepped increments, rather than gradually. The stepped increments occur at wavelength multiples to efficiently transmit the megasonic energy. For example, in one embodiment, the thinnest portion 158 of the probe has a length of approximately nineteen wavelengths, the next larger diameter portion 160 is about three wavelengths in axial length and the largest diameter portion 162 is about four wavelengths in axial length. The goal is to simulate the results obtained with the tapered arrangement of Figure 1.

Figures 5a-5c depict further embodiments for the tip of the probe. The different probe tips may help cover a portion of the wafer surface that otherwise would not be covered by a flat probe end 157. The probe may have a conical tip 164, an inverted conical tip 166, or a rounded tip 168.

The probe larger end 104d is acoustically coupled to a heat transfer member 134 and is physically supported by that member. The probe end face is preferably bonded or glued to the support by a suitable adhesive material. In addition to the bonding material, a thin metal screen 141, shown in Figure 3, is sandwiched between the probe end and the member 134. The screen with its small holes filled with adhesive provides a more permanent vibration connection than that obtained with the adhesive by itself. The screen utilized in a prototype arrangement was of the expanded metal type, only about .002 inch thick with flattened strands defining pockets between strands capturing the adhesive. The adhesive employed was purchased from E.V. Roberts in Los Angeles and formed by a resin identified as number 5000, and a hardener identified as number 61. The screen material is sold by a U.S. company, Delkar. The probe can possibly be clamped or otherwise coupled to the heat transfer member so long as the probe is adequately physically supported and megasonic energy is efficiently transmitted to the probe.

The heat transfer member 134 is made of aluminum, or some other good conductor of heat and megasonic energy. In the arrangement illustrated, the heat transfer member is cylindrical and has an annular groove 136, which serves as a coolant duct large enough to provide an adequate amount of coolant to suitably cool the apparatus. Smaller annular grooves 138, 139 on both sides of the coolant groove 136 are fitted with suitable seals, such as O-rings 135, 137 to isolate the coolant and prevent it from interfering with the electrical connections to the transducer 140.

The transducer 140 is bonded, glued, or otherwise acoustically coupled to the rear flat surface of the heat transfer member 134. A suitable bonding material is that identified as ECF 550, available from Ablestick of Gardena, California. The transducer 140 is preferably disc shaped and has a diameter larger than the diameter of the rear end of the probe section 104d to maximize transfer of acoustic energy from the transducer to the probe. The heat transfer member is preferably gold-plated to prevent oxidizing of the aluminum and, hence, provide better bonding to the transducer and the probe.

The transducer 140 and the heat transfer member 134 are both contained within the housing 120 that is preferably cylindrical in shape. The heat transfer member is captured within an annular recess 133 in an inner wall of the housing 120.

The housing is preferably made of aluminum to facilitate heat transfer to the coolant. The housing has openings 144 and 146 for the outlet 122 and the inlet conduit 124 for the liquid coolant. On its closed end, the housing 134 has an opening 152 for the electrical connections 126 and 154. Openings 148, 150 allow a gaseous purge to enter and exit the housing 120.

An open end of the housing 120 is attached to the annular plate 118 having the central opening 132 through which extends the probe rear section 104d. The annular plate has an outer diameter extending beyond the housing 120 and has a plurality of holes organized in two rings through an inner ring of holes 131, a plurality of connectors 128, such as screws, extend to attach the plate 118 to the housing 120. The annular plate 118 is mounted to the tank wall 100 by a plurality of threaded fasteners 117 that extend through the outer ring of plate holes 130 and thread into the tank wall 100. The fasteners also extend through sleeves or spacers 116 that space the plate 118 from the tank wall. The spacers position the transducer and flared rear portion 104b of the probe outside the tank so that only the cleaning portion of the probe and the probe tip extend into the tank. Also, the spacers isolate the plate 118 and the housing from the tank somewhat, so that vibration from the heat transfer member, the housing and the plate to the wall is minimized.

The processing tank 101 is made of material that does not contaminate the wafer. The tank should have an inlet (not shown) for introducing fluid into the tank and an outlet (not shown) to carry away particles removed from the article.

As the size of semiconductor wafers increases, rather than cleaning a cassette of wafers at once, it is more practical and less expensive to use a cleaning apparatus and method that cleans a single wafer at a time. Advantageously, the size of the probe of the present invention may vary in length depending on the size of the wafer to be cleaned.

A semiconductor wafer 106 or other article to be cleaned is placed on the support 108 within the tank 101. The wafer is positioned sufficiently close to the probe so that the agitation of the fluid between the probe and the wafer loosens particles on the surface of the wafer. Preferably, the distance between the probe and surface of the wafer is no greater than about .1 of an inch.

The motor 112 rotates the support 108 beneath the probe 104 so that the entire upper surface of the article is sufficiently close to the vibrating probe 104 to remove particles from the surface of the article. To obtain the necessary relative movement between the probe and the wafer 106, an arrangement could be provided wherein the wafer is moved transversely beneath the probe. Also, an arrangement could be provided wherein the support 108 remains in place while a probe moves above the surface of the wafer 106.

When the piezoelectric transducer 140 is electrically excited, it vibrates at a high frequency. Preferably the transducer is energized at megasonic frequencies with a voltage consistent with the probe size. The vibration is transmitted through the heat transfer member 134 and to the elongated probe 104. The probe 104 then transmits the high frequency energy into cleaning fluid between the probe and the wafer. One of the significant advantages of the arrangement is that the large rear portion of the probe can accommodate a large transducer, and the smaller forward probe portion concentrates the megasonic vibration into a small area so as to maximize particle loosening capability. Sufficient fluid substance between the probe and the wafer will effectively transmit the energy across the small gap between the probe and the wafer to produce the desired cleaning. As the surface area of the wafer 106 comes within close proximity to the probe 104, the agitation of the fluid between the probe 104 and the wafer 106 loosens particles on the semiconductor wafer 106. Contaminants are thus vibrated away from the surfaces of the wafer 106. The loosened particles may be carried away by a continued flow of fluid.

Applying significant wattage to the transducer 140 generates considerable heat, which could prevent damage to the transducer 140. Therefore, coolant is pumped through the housing 120 to cool the member 134 and, hence, the transducer.

A first coolant, preferably a liquid such as water, is introduced into one side of the housing 120, circulates around the heat transfer member 134 and exits the opposite end of the housing 120. Because the heat transfer member 134 is made of a good thermal conductor, significant quantities of heat may be easily conducted away by the liquid coolant. The rate of cooling can, of course, be readily monitored by changing the flow rate and/or temperature of the coolant.

A second, optional coolant circulates over the transducer by entering and exiting the housing 120 through openings 148, 150 on the closed end of the housing. Due to the presence of the transducer 140 and the electrical wiring 142, 154, an inert gas such as nitrogen is used as a coolant or as a purging gas in this portion of the housing.

An alternative arrangement for coupling the probe end 104b to the member 134 is illustrated in Figure 11. Instead of having the probe bonded to the member 134, a so-called vacuum grease is applied to the screen 141, and the probe is pressed against the member 134 by a coil spring 143. Vacuum grease is a viscous grease which can withstand pressures on opposite sides of a joint without leaking or being readily displaced. In a prototype

arrangement, the combination of the grease and the metal spring provided a reliable acoustic coupling. As may be seen in Figure 11, the housing 120 instead of being mounted directly to the plate 118, is mounted by standoffs 145 to the plate 118. The sleeves 116 and the fasteners 117 are shorter than that shown in Figure 2, such that the plate 118 surrounds the tapered portion of the probe. This leaves a gap between the housing 120 and the plate 118. The coil spring 143 is positioned in this gap and compressed between the plate 118 and the tapered portion of the probe. Thus, the spring presses the probe toward the member 134. This arrangement acoustically couples the probe to the heat transfer member 134. A Teflon sleeve 149 is preferably positioned over the first coil of the spring 143 adjacent the probe so that the metal spring does not damage the quartz probe.

An arrangement is illustrated in Figure 6, wherein the probe assembly of Figure 1 is shown in conjunction with a tank 200 which is open on its upper end and has a drain line 202 in its lower end. The probe 104 is shown extending through a slot 203 into the tank above a wafer 106 mounted on a suitable support 208 including an annular rim 208a, a plurality of spokes 208b, joined to a hub 208c positioned on the upper end of a shaft 210 rotated by a motor 212.

In use, deionized water or other cleaning solution is sprayed onto the upper surface of the wafer from a nozzle 214 while the probe 104 is being acoustically energized. The liquid creates a meniscus 216 between the lower portion of the probe and the adjacent upper surface of the rotating wafer. This is schematically illustrated in Figure 7. The liquid provides a medium through which the megasonic energy is transmitted to the surface of the wafer to loosen particles. These loosened particles are flushed away by the continuously flowing spray and the rotating wafer. When the liquid flow is interrupted, a certain amount of drying action is obtained through centrifical force of the liquid off of the water.

The probe assembly may be conveniently mounted on a suitable support, schematically illustrated at 116. The support is capable of pivoting the assembly upwardly, as indicated by the arrow 118, to facilitate the installation and removal of wafers. Alternatively, the slot 203 may instead be formed as a hole, closed at the top, and the probe may be moved radially in and out.

Figure 8 illustrates an alternative or addition to the arrangement of Figure 7 wherein both the lower and upper sides of a wafer are cleaned. A spray nozzle 254 extends through a side wall of a tank 200 and is angled upwardly slightly so that cleaning fluid may be sprayed between the spokes 208b and onto the lower surface of a wafer 106 and is directed radially inwardly so that as the wafer rotates, the entire lower surface is sprayed with the fluid. The wafer is subjected to megasonic energy by the probe 104 in the same manner as described above in connection with Figure 6. This agitation vibrates the wafer as well as the fluid on the lower surface of the wafer which is radially aligned with the probe as the wafer rotates. This agitation loosens particles on the lower surface of the wafer, and the particles are flushed away with the fluid which falls or drips from the lower surface of the wafer.

Various fluids may be employed as the spray applied to the wafer in Figures 6 and 8. In addition to liquid or high pressure gas, so-called dry ice snow may be applied. Va-Tran Systems, Inc. of Chula Vista, California markets a product under the trademark SNO GUN for producing and applying such material. A major advantage of

that approach is that there is no disposal problem after cleaning. Contamination is carried away from the clean surface in a stream of inert, harmless vapor. Disposal costs of cleaning media are eliminated. Advertising literature regarding the SNO GUN product states that cleaning with dry ice snow removes particles more thoroughly than blowing with dry nitrogen. It is said that the device removes even sub-micron particles as tiny as .2 microns, which are difficult or impossible to remove with a nitrogen jet. Such technology is further described in U.S. Patent No. 5,364,474, which is incorporated herein by reference.

Referring to Figure 9, the probe assembly of Figure 1 is shown mounted to a wall of a tank 300. The probe 104 extends generally horizontally through central openings in a plurality of vertically orientated substrates such as "compact disks" 302. The disks may be mounted in a cassette 306 immersed in the tank with the holes in the disks aligned with the probe. The cassette carrying the disks can then be moved laterally so that the probe extends through the holes in the disks, without actually contacting the disks. The tank is filled with liquid, such as deionized water to completely cover the disks. The probe is then vibrated by megasonic energy in the manner described above in connection with Figure 1. The agitation produced by the probe is transmitted into the cleaning liquid between the disks to loosen particles on the surfaces of the disks. The energy propagates radially outward from the probe such that both sides of each disk are exposed to such energy. Cleaning liquid may be introduced into the container in continuous flow and allowed to overflow the upper end of the container to carry away loosened particles.

Because some megasonic energy will be transmitted through the end of the probe with the probe tip immersed in the liquid, a small cap 306 is positioned on the tip of the probe with the cap containing an air space 308 between two glass walls 306a and 306b, as shown in Figure 9a. Since megasonic energy does not travel through ambient air to any significant degree, the cap prevents the loss of energy through the end of the probe. An alternative cap 310 shown in Figure 9b employs a short section of glass tubing 212 attached to the end of the probe. As seen, the outer diameter of the tube is equal to the outer diameter of the probe, and the outer end of the tube spaced from the probe is closed by a disc 314.

Figure 10 illustrates another embodiment of the probe of the invention. A probe assembly 400 is shown which is similar to the assembly of Figure 1 except that the probe 404 is much shorter than the probe 104 in Figure 1. In addition, the assembly 400 is oriented with the probe extending generally vertically, generally perpendicular to the surface of the horizontal wafer 106. Cleaning fluid is applied to the upper surface of the wafer, and the lower tip of the probe is in contact with this fluid. Consequently, megasonic energy is transmitted through this medium onto the surface of the wafer causing loosening of particles. Since the sides of the probe are not exposed to this medium, there is no appreciable megasonic energy transmitted from the vertical sides of the probe. Instead, such megasonic energy is concentrated into the tip. The tip can be moved radially with respect to the wafer as the wafer rotates so as to apply megasonic energy to the entire surface of the wafer. Alternatively, the probe may traverse the entire upper surface. Any suitable support 410 containing a mechanism to provide the desired movement may be employed.

As mentioned above, the preferred form of the probe assembly includes a probe made of inert material such as quartz and a heat transfer member coupled to the rear of the probe made of a good heat conducting material such as aluminum. Since it is the cylindrical portion of the probe which is in contact with the cleaning fluid and is positioned adjacent the wafer, an alternative arrangement could be devised wherein a forward portion, such as section 104a in Figure 1 could be made of the inert material and the rear portion 104b could be made of aluminum and hence could be made as one piece with the heat transfer member 134. This of course means that the joint between the two components would be at the rear of the cylindrical portion 104a. While such a bonding area would not be as strong as the arrangement illustrated in Figure 1, it may be useful in certain situations.

In the other direction, there may be some applications in which it is not necessary to employ quartz or other such inert material for the probe. Instead, the entire probe could be made of aluminum or other such material. In that situation, the heat transfer member could then be made as a one-piece unit with the probe. Also, with a metal probe it may be practical to spray the cleaning fluid through the probe itself. For example in the arrangement of Figure 10, fluid inlet could be located in the side of the large diameter end of the probe and an outlet can be located in the end face of the small diameter probe end. The fluid would also serve as a coolant to cool the transducer, particularly if dry ice snow were employed.

It will be appreciated by those skilled in the art that various modifications and changes may be made without departing from the scope of the invention, and all such modifications and changes are intended to fall within the scope of the invention, as defined by the appended claims.

WHAT IS CLAIMED IS:

1. A cleaning apparatus comprising:

a probe made of a material which efficiently transmits vibration energy;

a heat transfer member made of material different from the probe attached to one end of said probe; and

a vibrator coupled to said member for vibrating said probe with energy transmitted through the member.

2. The apparatus of Claim 1 wherein said probe has an elongated configuration with a circular cross-section with one end of said probe being smaller in diameter than an opposite end of said probe.

3. The apparatus of Claim 2, wherein said probe comprises:

a tip;

a solid elongated, forward, cylindrical portion; and

a rear portion with a larger cross-section diameter than the cross-section diameter of said cylindrical portion.

4. The apparatus of Claim 3, wherein said cylindrical portion comprises approximately two-thirds of the total length of said probe.

5. The apparatus of Claim 1 wherein said vibrator comprises a transducer acoustically coupled to said heat transfer member and connected to a source of acoustic energy.

6. The apparatus of Claim 5 further comprising a housing enclosing said transducer and said heat transfer member with said probe extending beyond said housing through one side of said housing.

7. The apparatus of Claim 1 wherein said heat transfer member is made of aluminum.

8. The apparatus of Claim 7 wherein said heat transfer member is gold-plated.

9. The apparatus of Claim 1, wherein a cross-section of said heat transfer member is similar in shape to a cross-section of said rear portion of said probe.

10. The apparatus of Claim 1, further comprising a coolant passage for circulating a coolant in heat transfer relation with said heat transfer member for controlling the temperature of said apparatus.

11. The apparatus of Claim 10, including a housing enclosing said heat transfer member and said vibrator, wherein said passage includes an annular groove between said housing and said heat transfer member.

12. The apparatus of Claim 11, including a seal in said housing to isolate said coolant from said vibrator.

13. The apparatus of Claim 1, including a container for receiving a cleaning fluid and a wafer to be cleaned, said probe being supported so that one portion of the probe is positioned close to a wafer to be cleaned.

14. The apparatus of Claim 13, including a support in said container for supporting the wafer, said probe being radially positioned with respect to the wafer, and said support being rotationally mounted.

15. The apparatus of Claim 13, including a sprayer positioned to spray cleaning fluid onto the surface of the wafer to produce a layer of fluid between the probe and the surface of the wafer for transmitting vibrational energy to the surface of the wafer.

16. A cleaning apparatus comprising:

a container for receiving an article to be cleaned

a support for said article within said container;

an elongated probe;

a support for said probe that positions a portion of said probe in said container sufficiently close to said article so that particles on the surface of said article are loosened when said probe oscillates at a predetermined frequency to agitate said fluid; and

a transducer coupled to said probe, said transducer adapted to oscillate at a frequency for propagating sonic energy through such probe into said fluid between the probe and the article.

17. The apparatus of Claim 16, wherein said probe is positioned generally parallel to the surface of said article when positioned on said article support.

18. The apparatus of Claim 16, wherein the cross-section of said probe is circular and said probe comprises:

a tip;

a solid elongated cylindrical portion, wherein said tip and said cylindrical portion are contained within said container; and

a rear portion external said container and having a circular cross-section at one end equal in size to the cross-section of said cylindrical portion, and having an opposite end which is larger in diameter than said one end.

19. The apparatus of Claim 18, wherein the diameter of the cross-section of said rear portion of said probe increases gradually from said one end to said opposite end.

20. The apparatus of Claim 18, wherein the diameter of the cross-section of said rear portion of said probe increases in stepped increments.

21. The apparatus of Claim 18, wherein the length of said cylindrical portion of said probe is at least half the length of an article to be cleaned.

22. The apparatus of Claim 18, including:

a heat transfer member coupled to said rear portion of said probe and to said transducer;

a housing enclosing and supporting said heat transfer member;

a plate attached to said housing, said plate having an opening through which said probe extends; and

said plate being connected to said container for supporting said housing on the exterior of the container.

23. The apparatus of Claim 22, including a plurality of spacers to space said plate from said container.

24. The apparatus of Claim 22, further comprising an annular coolant groove between said housing and said heat transfer member.

25. An apparatus for cleaning semiconductor wafers comprising:

a tank for receiving cleaning fluid and a wafer to be cleaned;

a probe including an elongated portion extending into said tank through a tank wall, and including a rear portion positioned exterior to the container;

a transducer acoustically coupled to the rear portion of said probe to megasonically vibrate the probe; and

a housing enclosing said transducer and mounted to said tank and supporting the transducer and the probe with said probe elongated portion being supported in cantilever fashion.

26. The apparatus of Claim 25, including a heat transfer member positioned in said housing, the member being acoustically coupled to the probe rear portion and being acoustically coupled to said transducer.

27. The apparatus of Claim 26 including a metallic screen and a viscous material applied to the screen compressed between the probe and the heat transfer member to provide the acoustic coupling between the probe and said member.

28. The apparatus of Claim 27 including a spring urging the probe towards the heat transfer member to compress the grease and the screen therebetween.

29. The apparatus of Claim 28 including a plate spaced from but fixed to said housing, the plate having an opening through which said probe extends, said plate being spaced from but fixed to said tank; and wherein said spring surrounds said probe and is compressed between said plate and said probe rear portion.

30. A cleaning apparatus comprising an elongated probe made of an inert, non-contaminating material which efficiently transmits vibration energy, wherein said probe has a circular cross-section with one end of said probe being smaller in diameter than the other end of said probe, said probe including a solid, elongated, cylindrical portion, a rear portion with a larger cross-section diameter than the cross-section diameter of said cylindrical portion, and a disc shaped transducer acoustically coupled to said probe rear portion, the transducer having a considerably larger diameter than the diameter of said cylindrical portion so as to maximize the acoustic energy focussed in said cylindrical portion.

31. The apparatus of Claim 30, wherein said cylindrical portion is approximately two-thirds of the total length of said probe.

32. The apparatus of Claim 30, including a heat transfer member made of good heat conducting material acoustically coupled between the transducer and the probe.

33. A cleaning apparatus comprising:

a container for receiving cleaning fluid and an article to be cleaned;

a probe assembly including an elongated probe portion positioned within the container and a rear portion positioned outside of the container, said rear portion having a cross-section on one end substantially

equal in size to the cross-section of the elongated portion within the container and having an opposite end which is larger in cross-section than said one end; and

a transducer coupled to said opposite end adapted to oscillate at a frequency for propagating sonic energy into said container through said probe.

34. The apparatus of Claim 33, wherein the portion of said probe within said container is a solid cylindrical portion made of quartz.

35. A cleaning apparatus comprising:

a container for receiving cleaning fluid;

a probe assembly including an elongated probe extending through and generally perpendicular to a side wall of the container, the assembly including a transducer coupled to the probe for applying megasonic energy to the probe so as to cause vibration of the probe; and

one or more disk-like elements each having a central aperture, said elements being supported in the chamber in a generally spaced, parallel, vertical orientation so that when the elements are immersed in cleaning liquid, megasonic energy is transmitted radially outwardly from said probe along the surfaces of said elements to loosen particles on said elements.

36. An apparatus of Claim 35, wherein said probe assembly includes a transducer acoustically coupled to the rear portion of said probe.

37. The apparatus of Claim 36, wherein the cross-section of the portion of said probe coupled to said transducer is much larger than the cross-section of the forward rod-like portion of said probe.

38. The apparatus of Claim 37, including a housing enclosing the rear portion of said probe and said transducer, said housing being mounted to the exterior of said container.

39. The apparatus of Claim 38, including a heat transfer member coupled to the rear of said probe rear portion and to said transducer to conduct vibration from the transducer to the probe, said heat transfer member cooperating with said housing to form coolant passages for conducting heat away from said transducer.

40. The apparatus of Claim 35, wherein said probe is formed of quartz, and said forward rod-like portion has a cylindrical cross-section, and said probe rear portion has a generally cylindrical rear portion with a cross-section substantially larger than the forward rod-like portion, with the rear portion further including a transition section extending between the rod-like portion and the rear cylindrical portion.

41. Apparatus for cleaning a semiconductor wafer comprising:

a support for supporting the wafer generally;

a sprayer for spraying cleaning fluid on an upper surface of the wafer;

a sprayer for spraying cleaning fluid on a lower surface of the wafer;

a probe positioned adjacent the upper surface of the wafer for loosening particles on the upper and lower surfaces of the wafer when megasonic's energy is applied to the probe.

42. The apparatus of Claim 41 wherein said lower surface sprayer is oriented to direct fluid onto the wafer lower surface beneath the probe.

43. A method of cleaning an article, such as a semiconductor wafer, comprising the steps of:

positioning the article to be cleaned on a support;

placing an elongated rod-like probe with the elongated side of the probe sufficiently close to a generally flat surface of said article to loosen particles on the surface when said probe oscillates;

introducing fluid into a small gap between the probe and said surface;

vibrating said probe; and

producing relative movement between said article and said probe to cause the entire surface area of said article to be cleaned to be sufficiently close to said probe to loosen particles on the surface of said article.

44. The method of Claim 43, wherein said probe is vibrated by connecting a transducer to said probe and energizing said transducer to oscillate at a predetermined frequency.

45. The method of Claim 44, comprising the step of controlling the temperature of said transducer by conducting coolant in heat transfer relation with the probe.

46. The method of Claim 45, including controlling said temperature by positioning a heat transfer member between the probe and the transducer, and conducting coolant in contact with the heat transfer member.

47. The method of Claim 43 wherein said fluid introducing step includes spraying dry ice snow on the wafer.

48. A method of cleaning one or more thin disks, comprising:

positioning said disks in a container in a generally vertical orientation with a central opening in each of said disks being horizontally aligned to define a generally horizontal axis;

inserting an elongated rod-like probe through a wall of said tank into said disk openings, said rod being adapted to transmit megasonic energy into liquid within the tank; and

applying megasonic energy to a rear portion of said probe in a manner to cause the probe to vibrate and propagate megasonic energy within the liquid in the tank so as to loosen particles on said disks.

49. A method of cleaning a semiconductor wafer comprising:

supporting the wafer generally horizontally;

positioning a probe close to an upper surface of the wafer;

spraying cleaning fluid onto the upper surface and a lower surface of the probe so that a fluid coupling is formed between the probe and the upper surface of the wafer; and

applying megasonic energy to vibrate the probe and loosen particles on the upper and lower wafer surfaces.

50. The method of Claim 49 wherein the spraying on the wafer lower surface is aligned with the wafer portion beneath the probe.

51. The method of Claim 49 including producing relative movement between the wafer and the probe so that a portion of the upper surface of the wafer to be cleaned is close to the probe.

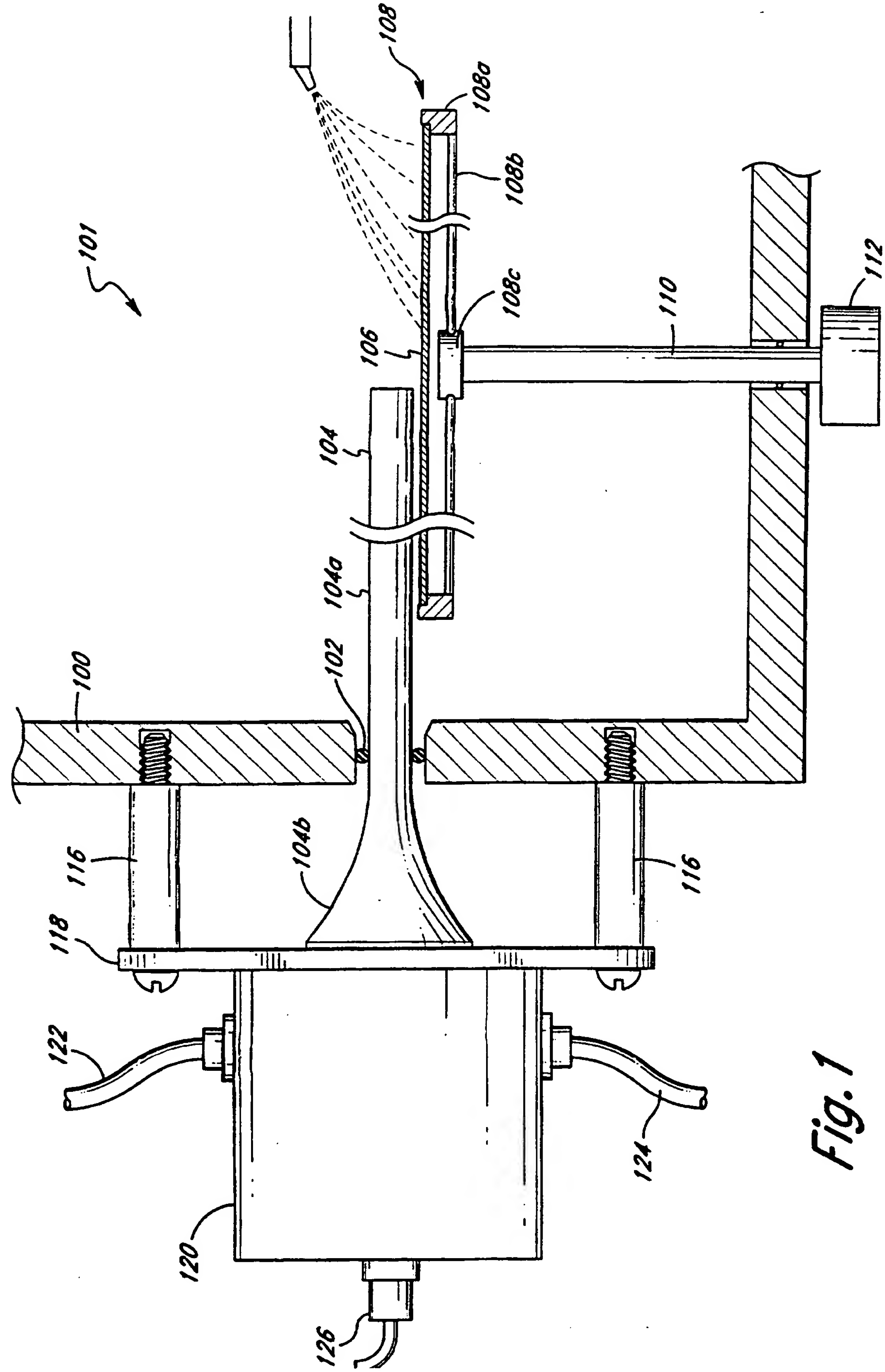
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Fig. 1

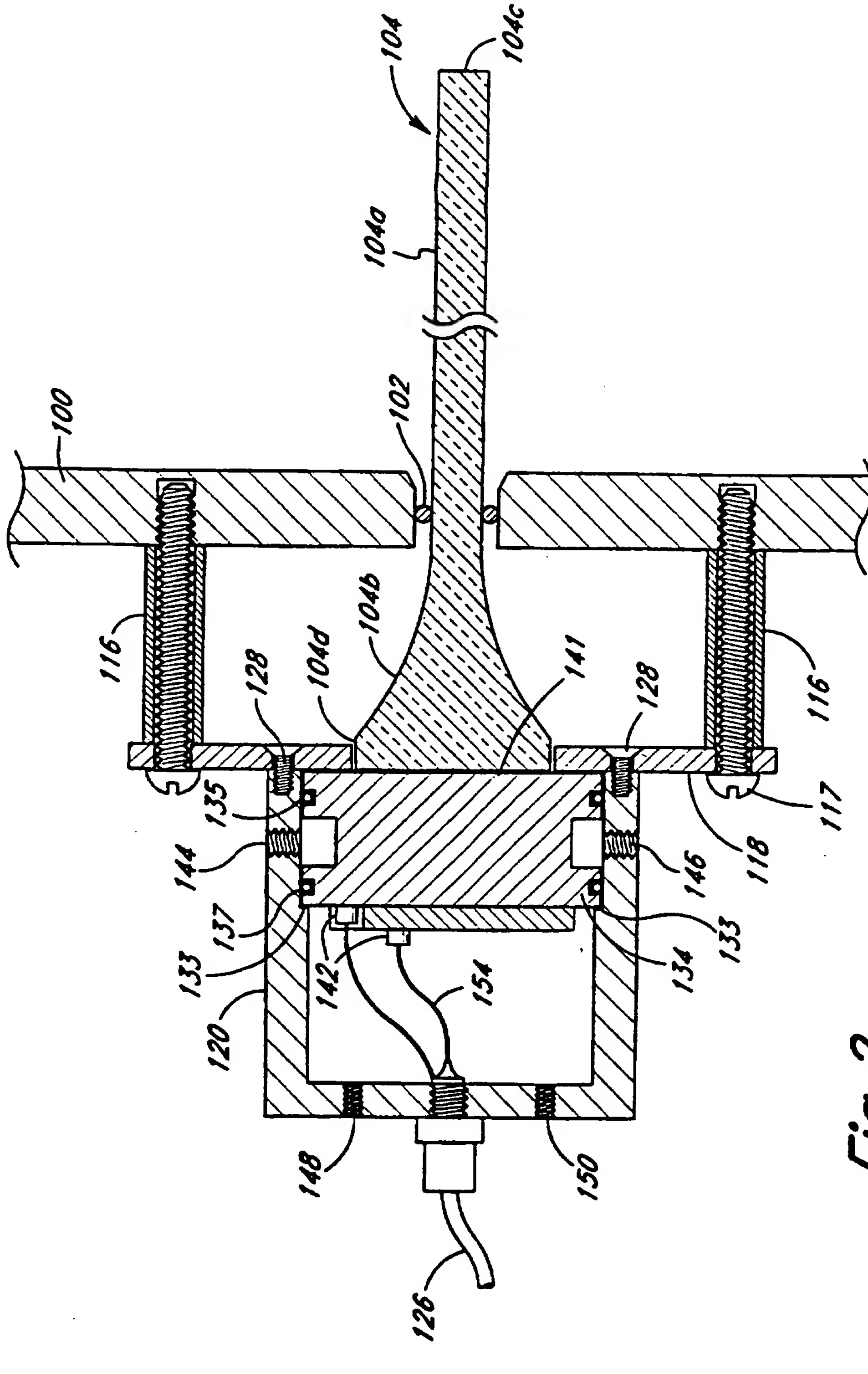
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Fig.2

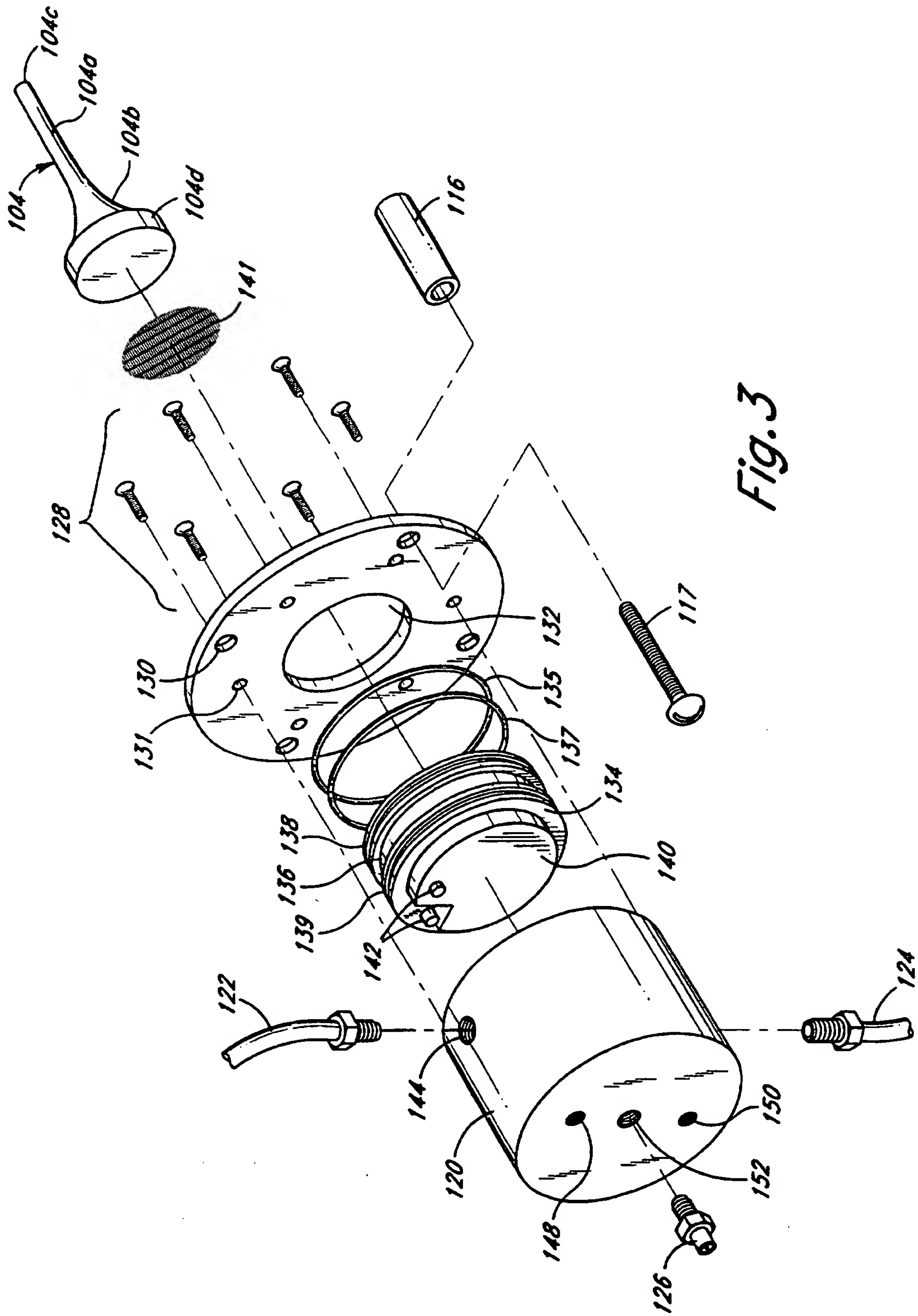
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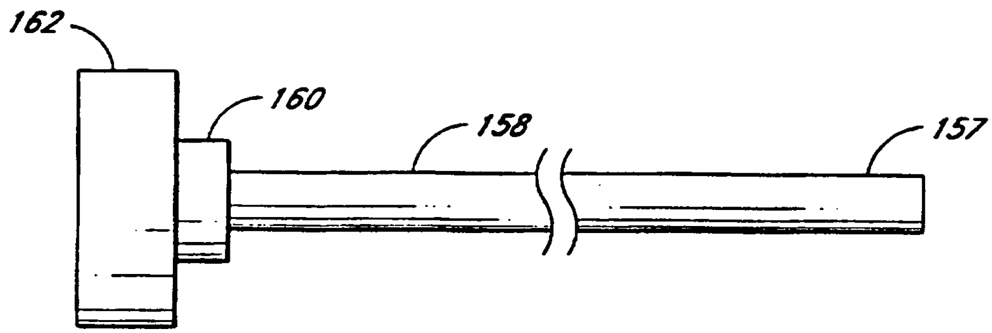
Fig.3



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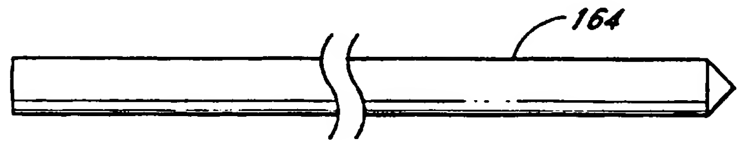

Fig. 5a

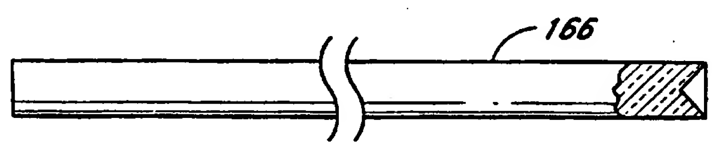

Fig. 5b

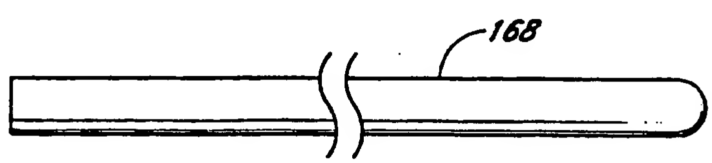

Fig. 5c

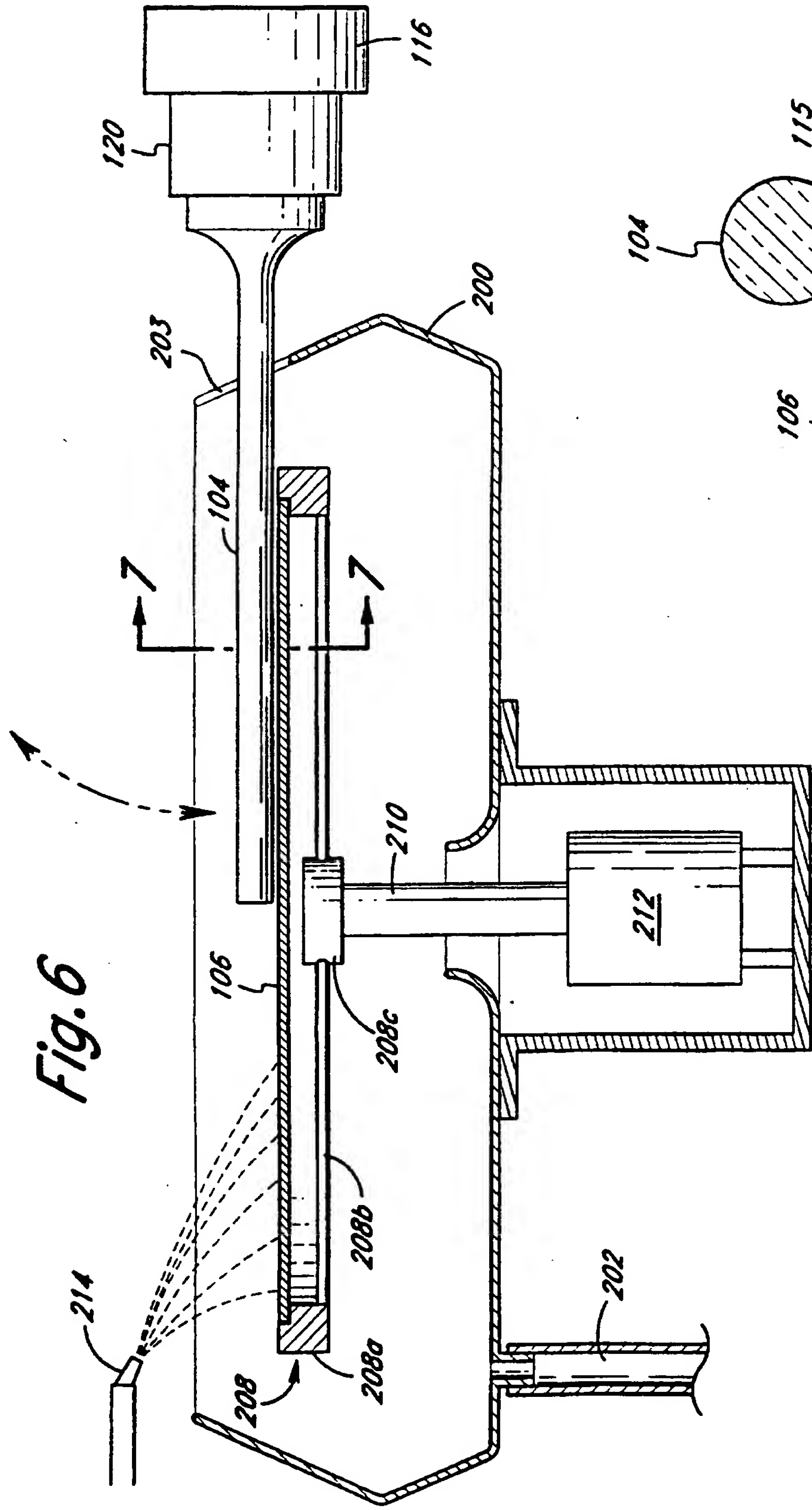
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Fig.6

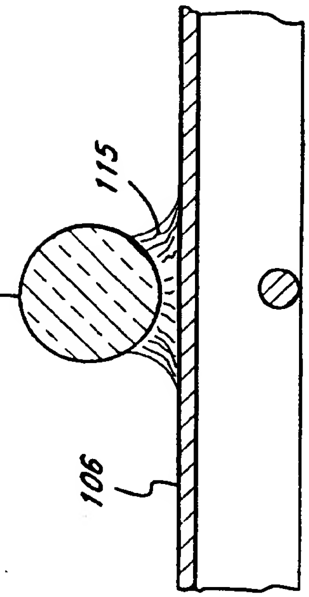
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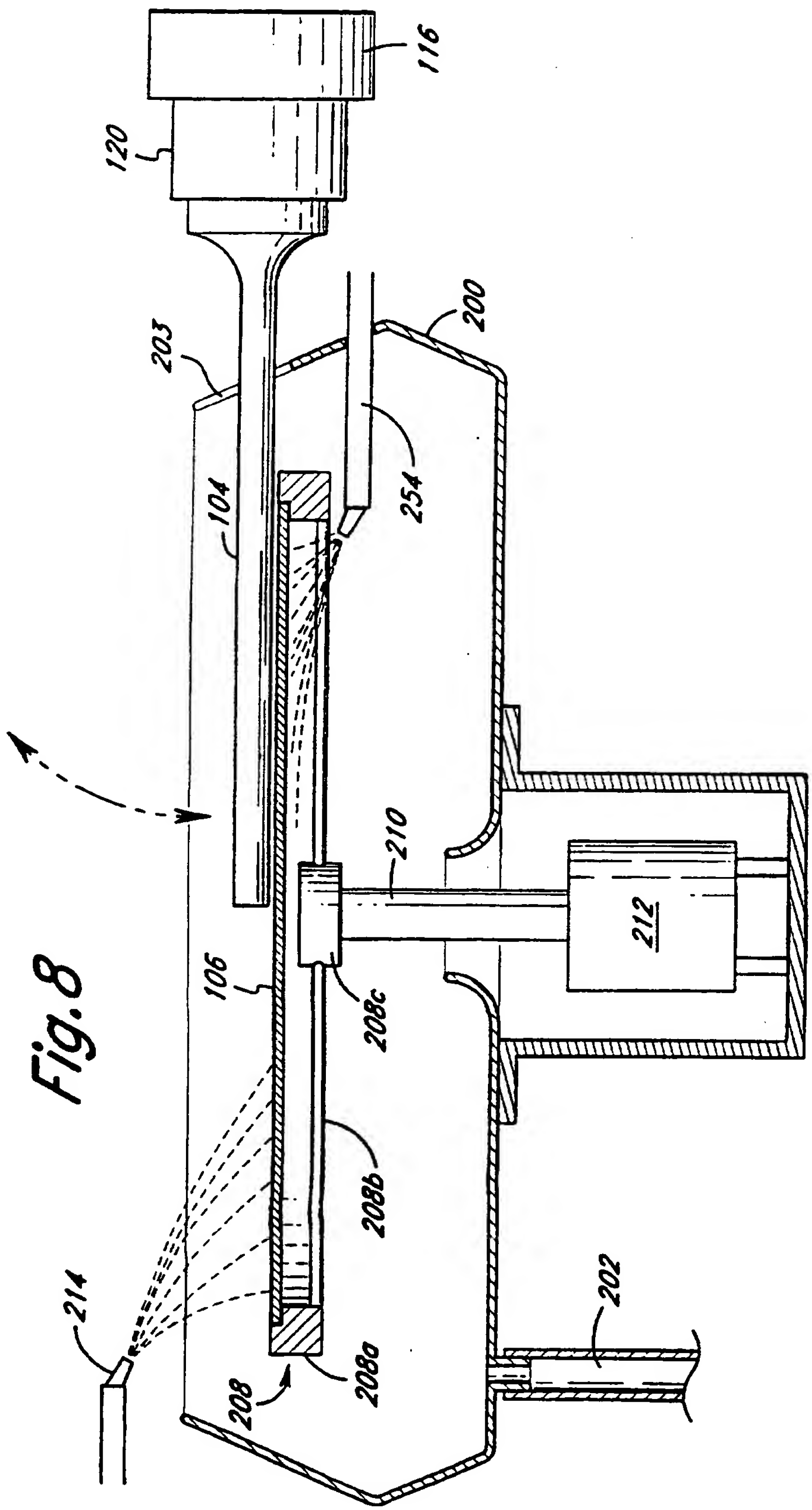
Fig.7



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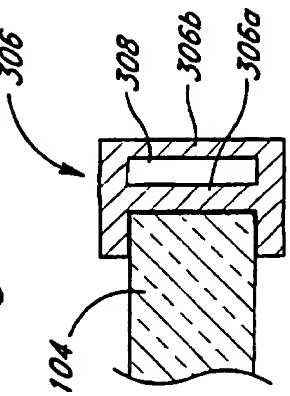

Fig.9a

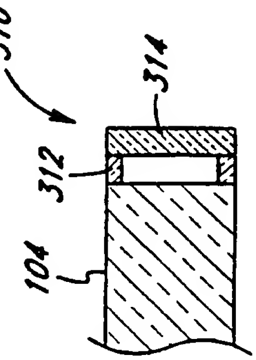

Fig.9b

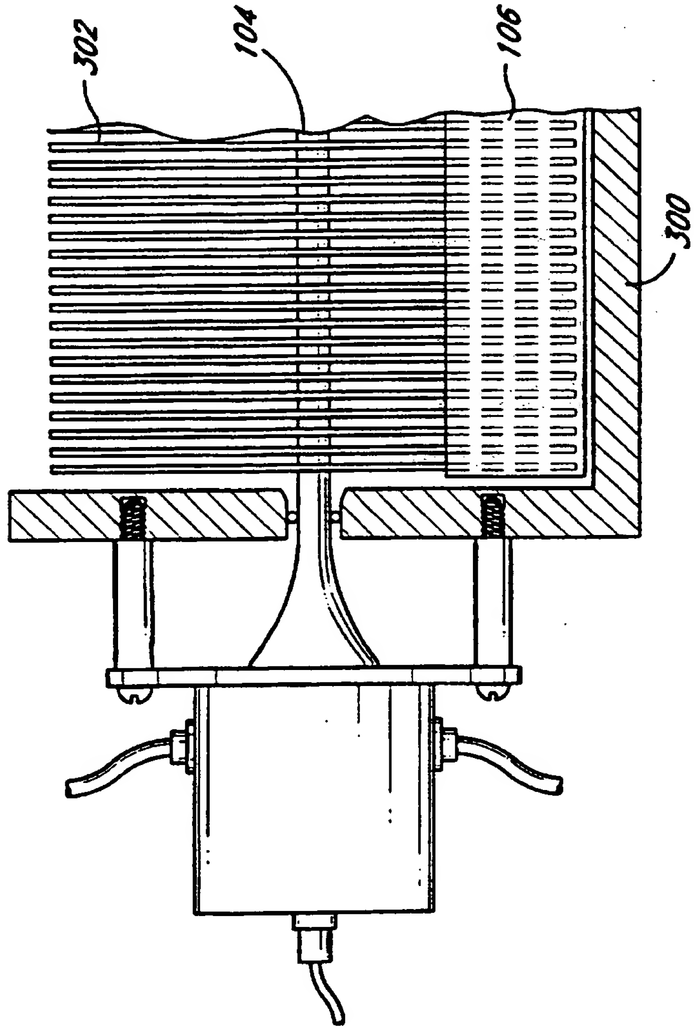

Fig.9

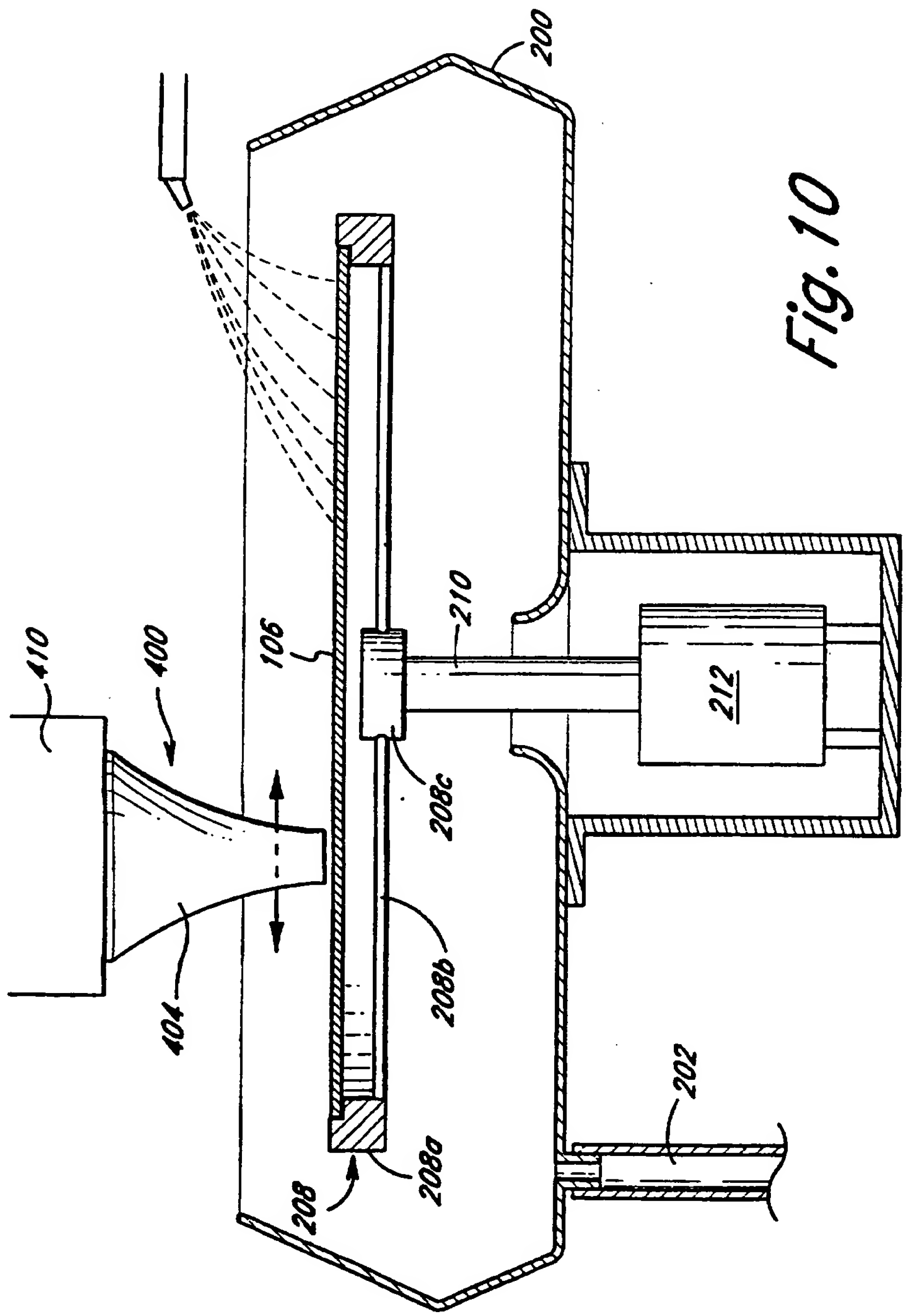

Fig. 10

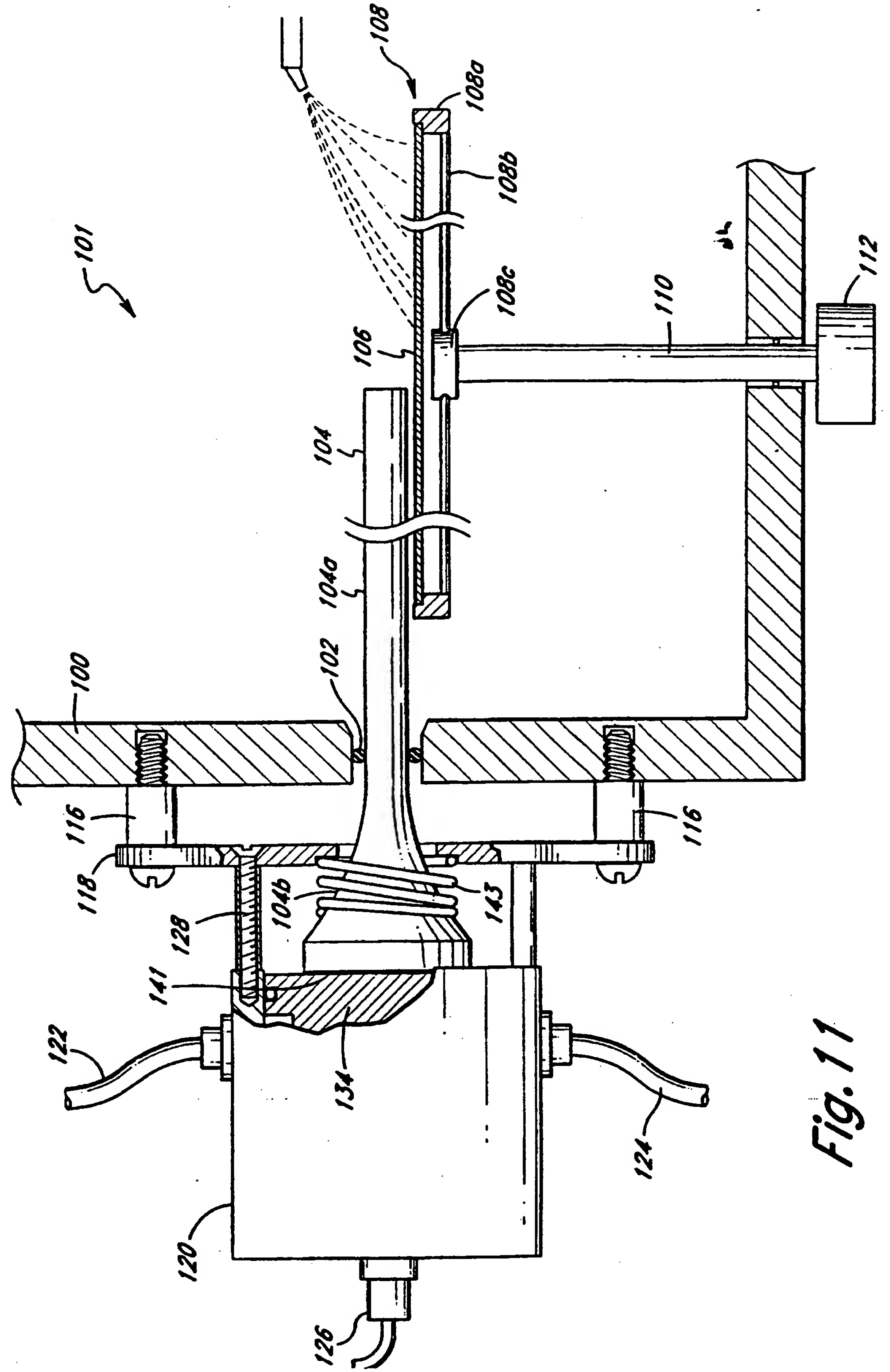
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Fig. 11

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 97/11812

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01L21/00 B08B3/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H01L B08B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 044 800 A (TELSONIC AG FUR ELEKTRONISCHE) 27 January 1982 see the whole document ---	1,2,5, 13,16, 18,25, 30,33, 35,36
A	US 4 326 553 A (HALL WILLIAM B) 27 April 1982 see the whole document ---	1-3,5, 13-16, 30,33, 41,43, 44,49,51
A	US 4 178 188 A (DUSSAULT JEAN G M ET AL) 11 December 1979 see the whole document ---	1,13-17, 25,41,49

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

4 November 1997

Date of mailing of the international search report

10/11/1997

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Authorized officer

Rieutort, A

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 97/11812

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0044800 A	27-01-82	DE 3027533 A	11-02-82
		BR 8108712 A	01-06-82
		WO 8200380 A	04-02-82
		JP 57501118 T	01-07-82
		US 4537511 A	27-08-85
US 4326553 A	27-04-82	NONE	
US 4178188 A	11-12-79	NONE	

International Application No
PCT/US 97/11812

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	"10 MHZ ULTRASONIC SILICON CLEANING TOOL" IBM TECHNICAL DISCLOSURE BULLETIN, vol. 37, no. 6A, 1 June 1994, page 585 XP000455894 -----	1